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THE EFFECT OF SUBSTRATE ON PRAWN DENSITY AND BIOMASS

Report No 87-31-K
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ABSTRACT

The hypothesis that the provision of artificial substrates can increase the growth and survival of prawns was tested. Post-larval prawns were raised in bare cages, cages with horizontal substrates and cages with horizontal/vertical substrates. Both substrate types resulted in significantly higher biomass (g/m^2) up to the 30th week of the 40-week study. The substrate with the horizontal and vertical components were more effective in increasing biomass than the substrates with only horizontal components. The percentage of animals remaining was significantly higher in the treatment cages than in the control cages for the first 10 weeks.

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EXECUTIVE SUMMARY

THE EFFECT OF SUBSTRATE ON PRAWN DENSITY AND BIOMASS

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The tropical freshwater prawn, Macrobrachium rosenbergii, is being considered for intensive culture in a waste-heat utilization scheme. This species has been described as aggressive and cannibalistic when reared at high densities; characteristics not conducive to intensive culture. However, antagonistic encounters can be reduced by providing physical structures (substrates) that would increase surface area and also separate the animals. The objective of this study was to test the hypothesis that the addition of artificial substrates to prawn culture facilities can increase production and survival.

Post-larval prawns were raised in bare cages, cages with horizontal substrates, and cages with horizontal/vertical substrates. Both substrate types resulted in significantly higher biomass (g/m^2) up to the 30th week of the 40-week study. The substrates with the horizontal and vertical components were more effective in increasing biomass than the substrates with only horizontal components. The percentage of animals remaining was significantly higher in the treatment cages than in the control cages for the first 10 weeks.

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To: Dr. D. Mills
Director of Research

THE EFFECT OF SUBSTRATE ON PRAWN DENSITY AND BIOMASS

1.0 INTRODUCTION

The tropical freshwater prawn, Macrobrachium rosenbergii, is being considered for intensive culture in a waste-heat utilization scheme. In intensive culture animals are stocked at high densities in small controlled systems as opposed to extensive culture in which animals are stocked at low densities in large outdoor natural systems. Intensive culture is being considered because it is less costly to maintain. However, Macrobrachium rosenbergii has been described as aggressive and cannibalistic when reared at high densities (Smith and Sandifer 1975); characteristics not conducive to intensive culture. The aggression may be associated with territoriality or mating. Antagonistic encounters can be reduced by providing physical structures (substrates) that would increase surface area and also separate the animals.

Smith and Sandifer (1975) increased the growth and survival of juvenile Macrobrachium rosenbergii raised in tank cultures by adding artificial substrates. They raised prawns in bare tanks, tanks with vertical substrates and tanks with horizontal substrates over a 12-week culture period. Although production increased with both substrate types, the horizontal substrates were found to be slightly more effective than the vertical substrates.

The objective of this study was to test the hypothesis that the addition of artificial substrates to prawn culture facilities can increase production and survival over a 40-week rearing period. The length of the culture period allowed us to assess the effectiveness of the substrates through sexual maturity and growth to market size (>30 g).

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Multi-tiered horizontal substrates and substrates with both horizontal and vertical components were assessed. The horizontal substrates provided vertical separation while the substrates with the horizontal and vertical components provided separation along both the vertical and horizontal planes. Biomass was translated into total and marketable yield per hectare to compare them with those reported in the literature.

2.0 METHODS

The experimental set up consisted of three control cages, three handling control cages, three cages with horizontal substrates, and three cages with horizontal/vertical substrates. The handling controls were added to estimate handling mortality at the end of the 40-week rearing period. The animals in the handling control cages were only weighed at the start and end of the experiment. Prawns in each of the remaining cages were weighed (wet weights) collectively at the start of the experiment and at 10-week intervals. Individual weights were taken on the last day of the experiment. At 30-weeks animals larger than 45 g were culled as is the practice in commercial operations. The weights of the culled prawns were included in the 40-week biomass estimates.

The cages measured 2 X 1 X 1.2 m (L X W X H) and were made of galvanized metal mesh. The horizontal substrates consisted of plywood frames with four horizontal layers of polyvinyl chloride (PVC) screening placed 15 cm apart. Each layer had an area of 1 m^2. Two of these horizontal substrate structures were placed in each of three cages. The horizontal/vertical substrates were similar to the horizontal substrates except for the addition of three vertical strips of PVC fly mesh placed in between the horizontal layers at points 20 cm apart. Again, two of these structures were placed into each of three cages. Handling and control cages were left bare. Total surface area was 8 m^2 in the control cages, 16 m^2 in the cages with the horizontal substrates and 20.5 m^2 in those with the horizontal/vertical substrates. The cages were placed into a 6 X 7 X 1 m cement pool equipped with recirculating water heating systems and aerators (Ontario Hydro Research Division Report No C85-12-K). Daily temperatures in the cement pool ranged from 28.3 to 29.5^{o} C with the exception of a one day low of 25.6^{o}C.

The prawns were obtained from Amorient Aquafarms Inc. of Kahuku, Hawaii. At the time of stocking the prawns were eight-week postlarvae with a mean weight of 0.26 g. Two hundred prawns were placed into each of the cages for a stocking density of 100/m^2 bottom surface. The density in terms of total surface area was 26.6/m^2 in the controls, 12.5/m^2 in the horizontal substrate cages and 9.8/m^2 in the horizontal/vertical substrate cages. Ninety-five prawns were found loose in the cement pool at the end

of the experiment. Some of these individuals were lost from one horizontal/vertical substrate replicate when its' sides collapsed. It was assumed that a constant number of prawns escaped from the remaining cages. Uniform mortality of approximately 10% was observed between the 20th and 30th week. The mortality was observed within 24-hours of the application of vinyl paint to a nearby facility in the building in which the experiment was conducted.

The animals were fed Rangen shrimp grower at a rate of approximately 5% of their mean biomass per day. They were offered a supplement of fresh fish flesh twice weekly for the first 20 weeks.

Analysis of variance was used to compare total biomass (production) and survival of the prawns at each time interval. In the analysis the split plot method was used with the treatment factor, replicate factor and covariate, time. A replicate factor was included to adjust for the variance between replicates. Total weight data were log transformed to meet the assumptions of the analysis. There were no significant differences ($P>0.5$) in the production and survival in the test and handling control cages. Thus the handling effect was considered to be negligible.

Results presented and discussed are means of the replicates.

3.0 **RESULTS**

Biomass was highest in the cages with the horizontal/vertical substrates, followed by the cages with the horizontal substrates and was lowest in the bare cages at all four observation times (Table 1).

In the control cages highest biomass of 437 g/m^2 was attained in week 20 and decreased to 378 g/m^2 in week 40. In the cages with the horizontal substrates biomass peaked at 579 g/m^2 in week 30 but decreased to 415 g/m^2 by week 40. With the horizontal/vertical substrates biomass was 642 g/m^2 in week 20 and 505 g/m^2 by week 40.

Statistical analysis indicated that at 10, 20 and 30-weeks, prawn biomass in the treatment cages was significantly higher ($P<0.5$) than in the controls. In week 20 the biomass in the cages with the horizontal/vertical substrates was also significantly higher than in the cages with the horizontal substrates. No significant differences were found at the start of the experiment (0-time) or at 40-weeks.

Table 1

MEAN TOTAL BIOMASS (g/m^2) OF PRAWNS IN BARE CAGES AND CAGES WITH SUBSTRATE

Cage	Experimental duration (Age of prawns in days postlarvae)				
	0 (8-weeks)	10-weeks (18-weeks)	20-weeks (28-weeks)	30-weeks (38-weeks)	40-weeks (48-weeks)
	Mean Biomass g per m^2 ± SD[1]				
Control	25.3 ± 0.7	268.0 ± 6.6	437.0 ± 5.7	426.7 ± 41.1	372.5 ± 6.1
Horizontal Substrate	25.7 ± 1.7	374.2 ± 23.5	556.2 ± 1.9	579.2 ± 31.0	414.7 ± 2.4
Horizontal/ Vertical Substrate	26.4 ± 0.5	385.0 ± 18.8	641.9 ± 38.1	592.4 ± 78.6	505.5 ± 90.3

[1]Standard Deviation

The largest difference in the percentage of animals remaining in the cages was observed at 10-weeks when it was significantly higher ($P<0.5$) in the treatment cages than in the controls. At this time the percentage of animals remaining was 90.3% in the cages with the horizontal/vertical substrates, 88.5% in the cages with the horizontal substrates and 78.5% in the cages with no added substrates. Beyond week 10 there were no significant differences ($P>0.05$) in the percentage of animals remaining. By week 40 the percentage of animals remaining in the cages ranged from 14.0 to 17.7% (Table 2).

Mean biomass productions at 40-weeks translate into total yields of 3725 kg/ha without the addition of substrates, 4147 kg/ha with horizontal substrates and 5050 kg/ha with horizontal/vertical substrates. Marketable yields, comprised of prawns > 30 g only, were 1361.5 kg/ha without the use of substrates, 1908.5 kg/ha with horizontal substrates and 2174 kg/ha with horizontal/ vertical substrates.

4.0 DISCUSSION

The increase in prawn biomass with the addition of substrates to the culture facilities was similar to the findings of Smith and Sandifer (1975). Differences in culture conditions in their study and ours, however, makes the comparison of biomass data difficult. They tested the use of artificial substrates over a 12-week culture period starting with 0.026 g animals stocked at densities of 515/m^2. In our study 0.26 g prawns were stocked at 100/m^2 and cultured for a period of 40 weeks.

As a gross comparison of increased biomass and percentage of animals remaining with the use of substrates Smith and Sandifer's (1975) 12-week data were compared to our 10-week data. Their biomasses ranged from 62 g/m^2 in the bare tanks to 274 g/m^2 in their tanks with horizontal substrates. Mean biomass in our bare cages was 268 g/m^2 and 374 g/m^2 in the cages with horizontal substrates. Survival in their tanks was 32% without substrates and 65% with horizontal substrates. The percentage of animals remaining in our study was 76% in the cages without substrates and 89% with horizontal substrates. The higher biomass and percentage of animals remaining obtained in our study may in part be related to the lower stocking density we used. Growth and survival of Macrobrachium rosenbergii have been found to vary inversely with population density (Sandifer and Smith 1975).

Our longer culture period allowed us to evaluate the use of substrates in rearing the prawns through sexual maturity. Macrobrachium rosenbergii generally reach maturity between 6 to 9 months of age (Malecha 1980). Mating activity can result in

Table 2

MEAN PERCENTAGE OF PRAWNS REMAINING IN BARE CAGES AND CAGES WITH SUBSTRATE

Cages	Experimental duration (Age of prawns in days postlarvae)			
	10-weeks (18-weeks)	20-weeks (28-weeks)	30-weeks (38-weeks)	40-weeks (48-weeks)
	Mean survival (%) ± SD[1]			
Control	78.5 ± 3.5	60.8 ± 2.5	34.2 ± 3.8	16.7 ± 4.9
Horizontal substrate	88.5 ± 1.5	62.0 ± 2.5	35.3 ± 2.3	14.0 ± 1.5
Horizontal/ Vertical substrate	90.3 ± 1.7	65.2 ± 2.1	35.5 ± 2.9	17.7 ± 1.9

[1]Standard Deviation

increased aggression in males. Males courting and protecting females are agonistic towards all approaching prawns (Ra'anan and Sagi 1985).

Maximum biomass was attained in the 20th week, the time at which the prawns started to reach sexual maturity indicated by the presence of ovigerous females. Between the 20th week and the end of the 40-week culture period prawn biomass had declined. Thus biomass increased until the animals reached sexual maturity with significantly higher biomass achieved with the use of substrates. Although biomass remained higher in the cages with the substrates than in the bare cages the substrates did not delay or prevent the eventual decline in biomass.

Between weeks 10 and 20 the use of substrates with horizontal and vertical components were more effective in increasing biomass production than the substrates with only horizontal components. The vertical strips provided horizontal separation. The horizontal plus vertical separation may have been more effective in reducing antagonistic encounters than vertical separation alone.

The percentage of animals remaining in the cages with substrates was higher than in the control cages up to week 10. At 20 weeks and beyond no differences were apparent. Thus, at the 20th week and beyond, the higher biomass in the cages with substrates was due to better growth. The substrates provided physical separation which probably reduced encounters between prawns. The improved growth may be a result of reduced energy expenditure associated with antagonistic encounters. This would be consistent with our finding that substrates with horizontal and vertical components, which provided separation along two planes, were more effective in increasing production than substrates with only horizontal components.

A study conducted by Sandifer et al (1982) under semi-intensive grow-out conditions using outdoor concrete tanks with substrates appears to be most similar to our study for gross comparative purposes. In one of their trials they stocked 1.0 g animals at a rate of 83/m^2. Biomass at the end of a 16-week grow-out period was the equivalent of 4700 kg/ha. At 20-weeks, a culture period closest to that used by Sandifer et al (1982), our best biomass estimate translated into a total yield of 6419 kg/ha. Thus the biomass attained in our cages with horizontal/vertical substrates compared well with that reported by Sandifer et al (1982).

Since density is known to affect survival and growth, the decrease in density in the cages due to escapes and culling, as well as the mortality observed during the application of vinyl paint to a nearby facility, may have affected the biomass estimates. However, the magnitude and direction of this bias is unknown.

At 40-weeks production in our cages with horizontal/vertical substrates translated into a yield of 5050 kg/ha. The marketable portion of this yield was only 2174 kg/ha. Intensive culture is expected to produce higher yields than extensive culture. Our marketable yield projected over a 12-month period would be 2530 kg/ha. This is lower than the average annual marketable yield of 3314 kg/ha obtained by Malecha et al (1981, in Malecha 1983) in extensive pond cultures in Hawaii.

5.0 SUMMARY AND CONCLUSION

The addition of horizontal or horizontal and vertical substrate types to the culture cages resulted in significantly higher biomass up to 30 weeks and higher percentages of animals remaining at the end of the first 10-weeks. The substrates with horizontal and vertical components were more effective in increasing biomass and the percentage of prawns remaining in the cages than the substrates with only horizontal components. The biomass in the cages with the horizontal/vertical components compared well with those reported in the literature for a semi-intensive study. However, the projected annual marketable portions were lower than those reported for extensive culture in Hawaiian ponds.

ACKNOWLEDGEMENTS

The laboratory experimentation was carried out by Mr. Peter Niklas, who also contributed to the project in the planning phase. Statistical analysis on the data were performed by Dr. Sheryl Bartlett of Operations Research Department.

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